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# *Indian Standard*

# TEST METHODS FOR MULTICHANNEL AMPLITUDE ANALYZERS

UDC 539.1.075 : 621.374.3

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 9

*March* 1988

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**IEC Pub 659 ( 1979 )**

*Indian Standard*

# TEST METHODS FOR MULTICHANNEL AMPLITUDE ANALYZERS

## National Foreword

This Indian Standard, which is identical with IEC Pub 659 ( 1979 ) 'Test methods for multichannel amplitude analyzers', issued by the International Electrotechnical Commission, was adopted by the Indian Standards Institution on the recommendation of the Nuclear Instrumentation Sectional Committee and approved by the Electronics and Telecommunication Division Council.

Wherever the words 'International Standard' appear, referring to this standard, they should be read as 'Indian Standard'.

Comma ( , ) has been used as a decimal marker in the adopted standard while in Indian Standards, the current practice is to use point ( . ) as the decimal marker.

## Cross Reference

In this Indian Standard, the following International Standards are referred to. Read in their respective places the following:

| *International Standard* | *Corresponding Indian Standard* |
|---|---|
| IEC Pub 578 ( 1977 ) Multichannel amplitude analyzers. Types, main characteristics and technical requirements | IS : 11885-1987 Specification for multichannel amplitude analyzers ( Identical ) |

The Technical Committee responsible for the preparation of this standard has reviewed the provisions of the following IEC standard and has decided that it is acceptable for use in conjunction with this standard:

IEC Pub 293 ( 1968 ) Supply voltages for transistorized nuclear instruments.

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard.

Nuclear Instrumentation Sectional Committee, LTDC 26 [ Ref : Doc : LTDC 26 ( 1035 ) ]

Adopted 28 January 1987

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## Scope

This standard is applicable to multichannel amplitude analyzers with linear conversion characteristics designed for determination of pulse amplitude distribution.

## 2. Object

This standard establishes acceptable test methods for each of the following parameters:

- minimum and maximum measurable signal amplitudes;
- intrinsic errors of the minimum and maximum measurable signal amplitudes;
- stability errors of the minimum and maximum measurable signal amplitudes;
- additional errors (or variations) of the minimum and maximum measurable signal amplitudes;
- channel width;
- intrinsic error of the channel width;
- stability error of the channel width;
- additional errors of the channel width;
- zero point;
- intrinsic error of the zero point;
- stability error of the zero point;
- additional errors of the zero point;
- effective range;
- integral non-linearity;
- differential non-linearity;
- dead time;
- maximum pulse rate to be measured;
- live time error.

This standard is not intended to imply that all the tests described herein are mandatory, but only that such tests as are carried out shall be performed in accordance with the procedures given herein.

## 3. General

3.1 The list of parameters to be tested, rules for and sequence of the tests are specified in the relevant IEC standards. In addition, they are to be specified in the technical documentation to be supplied with the analyzer under test.

Parameters covered in this standard are defined in IEC Publication 578: Multichannel Amplitude Analyzers. Types, Main Characteristics and Technical Requirements.

The common symbols used in this standard are defined in Appendix A

3.2 Each test shall be started on a fully adjusted analyzer after the warm-up time* given in the specification. If it is necessary to make any adjustment during a measurement, other than those normally associated with the operation of the analyzer, the instrument is switched off and allowed to cool. The instrument is then switched on and after the warm-up time the test is restarted.

3.3 The measurement of any parameter value, its intrinsic error and stability error shall be carried out under the following reference conditions:

- the pulse shape shall be specified;
- the minimum channel width available shall be used. Where the memory size is less than the number of quantization levels, the analyzer digital offset should be used;

- ambient temperature 20 ± 5 °C**;
- relative humidity 50% to 80%;
- atmospheric pressure 100 ± 4 kPa (750 ± 30 mm Hg);
- the reference values of mains supply voltage and frequency shall correspond to those stated in Clause 4 of IEC Publication 293: Supply Voltages for Transistorized Nuclear Instruments. Tolerances on these reference values shall be ±2% and ±1% respectively.

*Note.* – In measurements of stability errors, not less than ten measurements shall be performed at equal time intervals.

3.4 The measurement of additional errors should be made according to the test procedure of this standard.

The measurements are performed in the following order.

3.4.1 Additional error (variation) due to mains voltage changes at reference temperature:

*a)* Mains voltage equal to nominal value is provided by an automatic transformer or a voltage stabilizer. The readings shall be taken after the warm-up time.

*b)* Mains voltage shall be increased by 10% compared with the nominal value. The readings shall be taken after time sufficient for further variation to have negligible effect on the determination of the error. This time may be much shorter than the warm-up time.

*c)* Mains voltage shall be decreased by 10% compared with the nominal value and the variation due to voltage change of – 10% is determined as described in the previous case.

---

* Warm-up time is an interval of time between the moment of switching on the instrument and the moment when the analyzer in the rated range of use begins to meet specifications.

** It is recommended that the temperature be controlled within narrower limits.

3.4.2 Additional error (variation) due to temperature changes at reference mains voltage:

*a)* The analyzer shall be placed in a climatic chamber in which the temperature is equal to 20 °C; it shall be switched on and after the warm-up time the measurements shall be made. The temperature in the chamber shall be increased to 35 °C and maintained constant with the tolerance of ±2 °C for a sufficient time to permit the equipment to stabilize. The measurement is then carried out.

*b)* Two similar measurements shall be made as in Item *a)* of this sub-clause, except that the temperature is now lowered to 10 °C.

The additional error is determined from the change of the value of the parameter to be measured.

## 4. Test methods

### 4.1 *Minimum and maximum measurable signal amplitudes*

### 4.1.1 *Apparatus*

*a)* A precision pulse generator with the following characteristics:

- the output pulse amplitude shall be adjustable from minimum to maximum values of measurable signal amplitude taking into account the error of these values and the output impedance of the generator and the input impedance of the analyzer;
- the error of the amplitude setting shall be sufficiently small so as not to affect the parameter to be measured;
- the timing parameters of output pulses shall meet the requirements of the specification supplied with the analyzer;
- the pulse repetition rate shall be adjustable so as not to exceed 0.01 $v_{max}$ and in addition it shall not exceed the reciprocal of the dead time corresponding to the pulse amplitude used.

*b)* A ratemeter (a scaler and a timer).

### 4.1.2 *Preparation for a test*

The circuit diagram of a test set-up is shown in Figure 1, page 38. The generator output is connected to the analyzer input by a suitable coaxial cable of a length which will not affect the measurement results. The ratemeter is connected to an analog-to-digital converter (ADC) output signal which indicates pulses accepted.

### 4.1.3 *Test procedure*

The pulse repetition rate of the precision pulse generator is measured previously by the ratemeter.

The analyzer is switched to the selected analysis mode. The discrimination threshold is set to allow for the full pulse-height measurement range. The waveshape of the generator output pulses is specified in the relevant specifications.

The pulse amplitude from the precision pulse generator is increased from its lowest level until the frequency of pulses accepted by the ADC is 50% of the generator frequency. The corresponding pulse amplitude $A_{L\,min}$ is noted and from this value the minimum measurable signal amplitude can be calculated. A similar measurement is made by increasing the pulse generator amplitude until the frequency of ADC accepted pulses falls to 50% of the pulse generator output. This amplitude $A_{L\,max}$ corresponds to the maximum measurable signal level.

### 4.1.4 *Processing of measurement data*

In order to determine the input pulse amplitudes which correspond to the response thresholds $A_{L\,min}$ and $A_{L\,max}$, it is necessary to take account of the input impedance of the analyzer and the output impedance of the generator.

### 4.1.5 *Intrinsic error of minimum or maximum measurable amplitude*

Intrinsic error of a single determination of the measurable amplitude is given by:

$$\pm \left| A_L - A_{LN} \right|$$

where:
$A_L$ is either maximum or minimum input amplitude and $A_{LN}$ is the rated value of either maximum or minimum measurable amplitude.

### 4.1.6 *Stability error of the measurable amplitude*

Stability error of the measurable amplitude is given by:

$$\pm \left| A_{Li} - \frac{1}{n} \sum_{j=1}^{n} A_{Lj} \right|_{max}$$

where:
$A_{Li}$ is the value of the amplitude to be measured ($A_{Lj}$) during the continuous operation period of the analyzer excluding the warm-up time, for which the absolute value of the difference is maximum
$n$ is the number of measurements (see note of Sub-clause 3.3)

### 4.1.7 *Additional error of the measurable amplitude due to temperature changes*

The additional error of the measurable amplitude due to temperature changes is given by:

$$\pm \frac{\left| A_{Lt} - A_L \right|_{max}}{\Delta t}$$

where:
$A_{Lt}$ is the value of $A_L$ at that temperature at which the absolute value of the difference is maximum
$\Delta t$ is the temperature difference

### 4.1.8 *Additional error of the measurable amplitude due to mains voltage changes*

The additional error of the measurable amplitude due to mains voltage changes is given by:

$$\pm \left| A_{LV} - A_L \right|_{max}$$

where:
$A_{LV}$ is the value of $A_L$ at that mains voltage at which the absolute value of the difference is maximum

### 4.2 *Channel width*

The channel width is usually derived from the ideal linear amplitude response (I.L.A.R.).

4.2.1 *Apparatus*

*a)* A precision pulse generator with the characteristics specified in Sub-clause 4.1.1*a)*.

*b)* A white noise generator with the following characteristics:

- the bandwidth shall cover the range of a few hertz to a few megahertz;
- the output voltage r.m.s. value shall be adjustable from a few millivolts to a few volts;
- the stability error of the statistical parameters of noise shall not significantly influence the peak shape.

*c)* A linear mixer with the following characteristics:

- two inputs;
- the bandwidth shall cover the range of a few hertz to a few megahertz;
- the non-linearity and stability error of the transmission factor shall not contribute to the error of the parameter to be measured.

*d)* A digital printer interfaced to the analyzer.

4.2.2 *Preparation for a test*

The circuit diagram of a test set-up is given in Figure 2, page 38.

The precision pulse generator output and the noise generator output are connected to the analyzer input via the linear mixer.

4.2.3 *Test procedure*

The analyzer is switched to the analysis mode at the full pulse-height measurement range.

The precise value of a pulse amplitude at the analyzer input ($A_p$) and the channel number $m_p$ corresponding to this amplitude are determined, taking into account the output impedances of the generators and the linear mixer, the input impedance of the mixer and the analyzer as well as the transmission factor of the mixer. The noise generator is switched on. Care should be taken that the statistical parameters (r.m.s. output voltage and bandwidth) of the white noise generator and the linear mixer do not distort the symmetric peak. The width of the peak is set so that there are approximately ten channels at 0.1 $N'_{max}$, where $N'_{max}$ is the maximum channel content in the peak.

Two measurements are performed in the lower part ($A_{po}$, $m_{po}$) of the range at about 0.1 $A_{max}$ and in the upper part ($A_{pe}$, $m_{pe}$) at about 0.9 $A_{max}$.

The order of magnitude of $N'_{max}$ shall be stated in the relevant specifications.

4.2.4 *Processing of measurement data*

The channel width is determined as the slope of the straight line joining the two experimental points ($A_{po}$, $m_{po}$ and $A_{pe}$, $m_{pe}$).

The channel width is given by:

$$H = \frac{A_{pe} - A_{po}}{m_{pe} - m_{po}} \text{ volt/channel}$$

if $A_p$ is in volts.

The exact position (in terms of an interpolated channel number) of each peak ($m_{po}$ and $m_{pe}$) is calculated as follows:

The channels $m_b$ and $m_h$ which correspond to the numbers of counts just below 0.1 $N'_{max}$ to the left and to the right of the peak are determined (Figure 3a, page 39). The number of counts in each of the channels from $m_{b+1}$ to $m_{h-1}$ is given by (Figure 3b, page 39) by:

$$N_i = N'_i - 0.1\ N'_{max}$$

Each channel content between $m_b$ and $m_h$ is replaced by the sum of the contents of all lower channels. The counts $N_i^*$ of channel $m_i$ so obtained ($b < i < h$) are given by:

$$N_i^* = \sum_{z=b+1}^{i} N_z$$

The maximum sum $N^*_{max} = N^*_{h-1}$ corresponds to the channel $m_{h-1}$.

The peak position $m_p$ corresponds to the abscissa, incremented by 0.5 channel, of the point of the ordinate 0.5 $N^*_{max}$ (Figure 3c, page 39).

It is given by:

$$m_p = m_k + 0.5 + \frac{N^*_{M/2} - N^*_k}{N^*_{k+1} - N^*_k}$$

where:
$N^*_{M/2} = 0.5\ N^*_{max}$
$m_k$ and $m_{k+1}$ are the numbers of channels where $N^*_k < N^*_{M/2}$ and
$N^*_{k+1} > N^*_{M/2}$, the difference between $m_{k+1}$ and $m_k$ being 1

### 4.2.5 *Intrinsic error of the channel width*

The intrinsic error of the channel width is given by:

$$\pm \frac{\left| H - H_N \right|}{H_N} \cdot 100\%$$

where:
$H_N$ is the rated channel width

### 4.2.6 *Stability error of the channel width*

Stability error of the channel width is given by:

$$\pm \frac{\left| H_i - \frac{1}{n} \sum_{j=1}^{n} H_j \right|_{max}}{\frac{1}{n} \sum_{j=1}^{n} H_j} \cdot 100\%$$

where:
$H_i$ is the value of the channel width $H_j$ measured during the continuous operation of the analyzer (excluding the warm-up time) at which the absolute value of the difference is maximum
$n$ is the number of measurements (see note of Sub-clause 3.3).

4.2.7 *Additional error of the channel width due to temperature changes*

The additional error of the channel width due to temperature changes is given by:

$$\frac{\left| H_t - H \right|_{\max}}{H \cdot \Delta t} \cdot 100\%$$

where:
$H_t$ is the value of the channel width at the temperature at which the absolute value of the difference is maximum
$\Delta t$ is the temperature difference

4.2.8 *Additional error of the channel width due to supply voltage changes*

The additional error of the channel width due to supply voltage changes is given by:

$$\pm \frac{\left| H_V - H \right|_{\max}}{H} \cdot 100\%$$

where:
$H_V$ is the value of the channel width at the supply voltage at which the absolute value of the difference is maximum

4.3 *Zero point*

4.3.1 *Apparatus*

Sub-clause 4.2.1 is applicable.

4.3.2 *Preparation for a test*

Sub-clause 4.2.2 is applicable.

4.3.3 *Test procedure*

The mode of the analyzer operation and test procedure shall be as described in Sub-clause 4.2.3.

4.3.4 *Processing of measurement data*

Sub-clause 4.2.4 is applicable.

4.3.5 *Intrinsic error of the zero point*

The intrinsic error of the zero point $a_o$ (Figure 4, page 40) is given by:

$$a_o = \frac{A_{po}\, m_{pe} - A_{pe}\, m_{po}}{m_{pe} - m_{po}}$$

The symbols correspond to those given in Sub-clause 4.2.4.

4.3.6 *Stability error of the zero point*

Stability error of the zero point is given by:

$$\pm \left| a_{oi} - \frac{1}{n} \sum_{j=1}^{n} a_{oj} \right|_{max}$$

where:

$a_{oi}$ is the value of the zero point $a_{oj}$ measured during continuous operation of the analyzer (excluding the warm-up time) at which the absolute value of the difference is maximum

$n$ is the number of measurements (see Sub-clause 3.3)

4.3.7 *Additional error of the zero point due to temperature changes*

The additional error of the zero point due to temperature changes is given by:

$$\pm \frac{\left| a_{ot} - a_{o} \right|_{max}}{\Delta t}$$

where:

$a_{ot}$ is the value of the zero point at that temperature at which the absolute difference is maximum

$\Delta t$ is the temperature difference

4.3.8 *Additional error of the zero point due to supply voltage changes*

The additional error of the zero point due to supply voltage changes is given by:

$$\pm \left| a_{ov} - a_{o} \right|_{max}$$

where:

$a_{ov}$ is the value of the zero point at the supply voltage at which the absolute value of the difference is maximum

4.4 *Integral non-linearity*

4.4.1 *Apparatus*

Sub-clause 4.2.1 is applicable.

4.4.2 *Preparation for a test*

Sub-clause 4.2.2 is applicable.

4.4.3 *Test procedure*

The order of test application, the mode of the analyzer operation and test procedures shall be as described in Sub-clause 4.2.3.

The number of measurement points over the whole scale shall be 10 to 20, the two points of Sub-clause 4.2.4 being included. The distribution of the measurement points over the scale shall be stated in the relevant specifications.

4.4.4 *Processing of measurement data*

The position of each peak is calculated according to Sub-clause 4.2.4. Deviations of experimental points from the ideal linear amplitude response (Figure 5, page 40) are given by

$$\Delta A_{pi} = A_{pi} - \left| \frac{A_{pe} - A_{po}}{m_{pe} - m_{po}} m_{pi} + \frac{A_{po}\, m_{pe} - A_{pe}\, m_{po}}{m_{pe} - m_{po}} \right|$$

The integral non-linearity is given by:

$$K_i = \pm \frac{\left| \Delta A_{pi} \right|_{max}}{A_{max}} \cdot 100\%$$

where:
$|\Delta A_{pi}|_{max}$ is the maximum absolute value of deviation

### 4.4.5 *Change of integral non-linearity due to temperature changes*

Change of integral non-linearity due to temperature changes is given by:

$$\pm \frac{\left| K_{it} - K_i \right|_{max}}{\Delta t} \; \%/^{\circ}\mathrm{C}$$

where:
$K_{it}$ is taken for the temperature at which the absolute value of the deviation is maximum
$\Delta t$ is the temperature difference

### 4.4.6 *Change of integral non-linearity due to supply voltage changes*

Change of integral non-linearity due to supply voltage changes is given by:

$$\pm \left| K_{iV} - K_i \right|_{max} \%$$

where:
$K_{iV}$ is taken for the value of supply voltage at which the absolute value of the deviation is maximum

## 4.5 *Differential non-linearity*

### 4.5.1 *General method*

Two methods are presented. The first one is general. The second (subsidiary) method is less rigorous and is permitted for analyzers with more than 4 096 quantization levels in order to reduce measurement time.

#### 4.5.1.1 *Apparatus*

*a)* A sliding pulse generator i.e. a pulse generator producing a uniform distribution of pulse-heights with the following characteristics:
  - the non-uniformity of pulse-height distribution on a full range shall not contribute to the error of differential non-linearity of the instrument under test;
  - the stability error of the mean value of pulse-height distribution during the time of measurement shall not contribute to the error of differential non-linearity of the instrument under test;
  - the lower and higher boundaries of uniform pulse-height distribution shall be smoothly adjusted from $A_{min}$ to $A_{max}$ taking into account the error of these values and output impedance of the generator and input impedance of the analyzer;
  - the timing parameters of output pulses as well as the average number of pulses per unit time shall comply with the requirements of the relevant specifications.

*b)* A digital printer interfaced to the analyzer.

4.5.1.2 *Preparation for a test*

The circuit diagram of a test set-up is given in Figure 6, page 40.

4.5.1.3 *Test procedure*

The analyzer is switched to the analysis mode at the full pulse-height measurement range for a time sufficient to reach a number of counts per channel compatible with good statistical accuracy of measurement.

The order of magnitude of this number of counts as well as the channel width of the analyzer under measurement shall be stated in the relevant specifications.

The measurement data, i.e. the number of counts in each channel $j$ of the analyzer, $N_j$, are recorded by a digital printer.

4.5.1.4 *Processing of measurement data*

Differential non-linearity is given by:

$$K_d = \pm \frac{\left| N_i - N_a \right|_{\max}}{N_a} \cdot 100\%$$

where:
$N_i$ is the value $N_j$ of the number of counts in the channel at which the absolute value of the difference is maximum
$N_a$ is the average number of counts per channel

Only the channels which are within the limits of the effective range are used to calculate differential non-linearity.

4.5.1.5 *Change of differential non-linearity due to temperature changes*

Change of the differential non-linearity due to temperature changes is given by:

$$\pm \frac{\left| K_{dt} - K_d \right|_{\max}}{\Delta t} \cdot \%/^\circ\mathrm{C}$$

where:
$K_{dt}$ is the value of differential non-linearity at that temperature at which the absolute value of the difference is maximum

4.5.1.6 *Change of differential non-linearity due to supply voltage changes*

Change of the differential non-linearity due to supply voltage changes is given by:

$$\pm \left| K_{dV} - K_d \right|_{\max} \%$$

where:
$K_{dV}$ is the value of differential non-linearity at that supply voltage at which the absolute value of the difference is maximum

### 4.5.2 *Subsidiary method*

### 4.5.2.1 *Apparatus*

*a)* A pulse generator as described in Sub-clause 4.5.1.1*a)*, which produces pulses with uniform density of pulse-height distribution over a limited range (e.g. from $V$ to $V + A$, Figure 7a, page 41). Such a generator may consist of a ramp generator, an adjustable d.c. source, a linear mixer and a linear gate (Figure 7b, page 41). A linear mixer is unnecessary if the ramp generator and the adjustable d.c. source are floating (not connected to earth) and can be connected in series (Figure 7c, page 41).

*b)* A digital printer interfaced to the analyzer.

### 4.5.2.2 *Preparation for a test*

The circuit diagram of a test set-up is given in Figure 7b or 7c.

### 4.5.2.3 *Test procedure*

The analyzer is switched to the analysis mode at the full pulse-height measurement range. In order to save measurement time, only a few regions of the full range can be tested.

The more critical regions of the range of the analog-to-digital converter shall be chosen such as minimum and maximum signal range, as well as a region located in the middle part of the range. For instance, if a 16 000 channel ADC is considered, three regions of 1 000 channels each can be tested, located in the lower, middle and higher part of the full range respectively.

Minimum value of pulse amplitude ($V$) and maximum value ($V + A$) are set so as to cover the above-mentioned regions.

The measurement time for each region is so determined as to reach a number of counts per channel compatible with good statistical accuracy of measurement. The order of magnitude of this number of counts per channel as well as the channel width, the number of the analyzer regions and their location shall be stated in the relevant specifications.

The measurement data, i.e. the number of counts in each channel of the analyzer region, $N$ are printed.

### 4.5.2.4 *Processing of measurement data*

Local differential non-linearity is given by:

$$K_{\mathrm{ld}} = \pm \frac{\left| N_{\mathrm{i}} - N_{\mathrm{a}} \right|_{\max}}{N_{\mathrm{a}}} \cdot 100\%$$

where:
$N_{\mathrm{i}}$ is the value of the number of counts $N_{\mathrm{j}}$ for which the absolute value of the difference is maximum
$N_{\mathrm{a}}$ is the average number of counts per channel for the chosen region of the range

The maximum of the three calculated values $K_{\mathrm{ld}}$ is an estimate of the differential non-linearity of the analyzer.

4.5.2.5 *Change of local differential non-linearity due to temperature changes*

Change of local differential non-linearity due to temperature changes is calculated by the formulae of Sub-clauses 4.5.1.5 and 4.5.2.4.

4.5.2.6 *Change of local differential non-linearity due to supply voltage changes*

Change of local differential non-linearity due to supply voltage changes is calculated by the formulae of Sub-clauses 4.5.1.6 and 4.5.2.4.

### 4.6 *Effective range*

4.6.1 *Apparatus*

Sub-clause 4.2.1 is applicable.

4.6.2 *Preparation for a test*

Sub-clause 4.2.2 is applicable.

4.6.3 *Test procedure*

Sub-clause 4.2.3 is applicable.

4.6.4 *Processing of measurement data*

Sub-clauses 4.2.4 and 4.3.4 are applicable.

4.6.5 The numbers of channels $m_\alpha$ and $m_\gamma$, which limit the effective range, are determined.

The upper and lower limits of the effective range are given by the formulae:

$$A_\alpha = H \cdot m_\alpha + a_0$$
$$A_\gamma = H \cdot m_\gamma + a_0$$

### 4.7 *Dead time of the analyzer**

4.7.1 *Apparatus*

A double-pulse generator with the following characteristics:

- the pulse amplitude shall be adjustable from $A_{\min}$ to $A_{\max}$;
- the error of the amplitude setting shall be sufficiently small so as not to affect the parameter to be measured;
- the value of the delay between pulses shall be smoothly adjustable from 0.7 $T_{\mathrm{d}\,\min}$ to 1.3 $T_{\mathrm{d}\,\max}$;
- the error of the delay setting shall not significantly affect the error in dead time measurement;
- the timing parameters of the output pulses shall meet the requirements of the specification supplied with the analyzer;
- the pulse repetition rate shall be adjustable so as not to exceed 0.01 $v_{\max}$.

---

* This measurement is only applicable to systems with direct access to the memory.

### 4.7.2 *Preparation for a test*

The circuit diagram of a test set-up is given in Figure 8, page 42. The generator output is connected to the analyzer input through a suitable coaxial cable. It is permissible to use a generator with two outputs, the generator being connected to the analyzer via a linear mixer. The cable length shall not affect the measurement.

### 4.7.3 *Test procedure*

The analyzer is switched to the analysis mode at the full pulse-height measurement range.

The pulse amplitude of the first (prompt) output is adjusted so as to record the pulses in channel $m_0$ which is within the range of 0.1 M to 0.2 M. The pulse amplitude of the second (delayed) output of the generator is adjusted arbitrarily within the limits of $A_{min}$ to $A_{max}$. By increasing smoothly the value of the delay time of the second pulse, the delay time $T_{do}$ is determined which corresponds to the beginning of the recording of the second pulse which is fixed on the screen of the oscilloscope ancillary to the analyzer.

Then a pulse amplitude of the first (prompt) output is adjusted so as to record the pulses in channel $m_e$ which is within the range of 0.8 M to 0.9 M, and the amplitude of the second (delayed) output is adjusted arbitrarily. By varying the delay time of the second pulse, the smallest delay time $T_{de}$ at which the second pulse is accepted by the analyzer is determined.

*Note.* – The time interval between pulse pairs should be at least ten times longer than the maximum delay between pulses.

### 4.7.4 *Processing of measurement data*

The results of the test described in Sub-clause 4.7.3 are compared with the values of the dead time calculated for the channel numbers $m_0$ and $m_e$ according to the relevant specifications, taking the rise times of the input signals into account.

The measured values of $T_{de}$ and $T_{do}$ shall not exceed these calculated values.

## 4.8 *Maximum pulse rate to be measured*

### 4.8.1 *Apparatus*

*a)* The generator described in Sub-clause 4.1.1;
*b)* A gamma-detector with an amplifier;
*c)* A ratemeter;
*d)* A $^{60}$Co source which provides a pulse rate not less than $v_{max}$ at the output of the detector;

*e)* A digital printer;
*f)* A linear mixer.

The apparatus models and the settings used for this test shall be specified.

### 4.8.2 *Preparation for a test*

The circuit diagram of a test set-up is given in Figure 9, page 42. The modes of operation for which the tests should be made shall be stated in the relevant specifications.

A generator and a detector are connected to the analyzer through a linear mixer. Cables shall be either sufficiently short or matched so that reflections do not affect the measurement.

### 4.8.3 *Test procedure*

The sensitivity threshold of the ratemeter is adjusted equal to $A_{min}$.

The analyzer is switched to the analysis mode at the full pulse-height measurement range. The channel width is fixed in accordance with the relevant specifications for the analyzer and the amplification factor is adjusted in such a way that the 1.33 MeV photopeak of $^{60}$Co falls in a channel between 0.65 and 0.75 of the effective range.

Set the pulse rate of the detector equal to 0.01 $v_{max}$ and adjust the pulse amplitude of a precision pulse generator so as to record the distribution maximum in a channel within the limits of 0.85 to 0.95 of the effective range. Perform a measurement and record the data with the digital printer. Adjust the pulse rate of the detector to $v_{max}$ and repeat the measurement and recording.

Adjust the amplification factor so that the 1.33 MeV photopeak of $^{60}$Co falls in a channel between 0.05 to 0.15 of the effective range with the pulser peak distinct and in a higher channel than the 1.33 MeV $^{60}$Co peak and repeat the measurement and recording for the detector pulse rate equal to 0.01 $v_{max}$ and $v_{max}$.

Measurement data, i.e. counts $N_j$ and the corresponding $m_j$, are recorded by the printer.

To ensure sufficient statistical accuracy, the number of counts registered in the channel corresponding to the maximum of the pulse generator peak shall not be less than 1 000. The actual number shall be stated.

### 4.8.4 *Processing of measurement data*

The position of the precision pulse generator peak in terms of an interpolated channel number is determined in accordance with Sub-clause 4.2.

The peak shift at the maximum pulse rate for the beginning and the end of the scale is given by:

$$\pm \left| m'_{po} - m''_{po} \right|$$

$$\pm \left| m'_{pe} - m''_{pe} \right|$$

where:

| | |
|---|---|
| $m_{po}$ and $m_{pe}$ | are the values of peak position for the beginning and the end of the scale respectively |
| $m'_p$ | corresponds to the pulse rate of 0.01 $v_{max}$ and |
| $m''_p$ | corresponds to $v_{max}$ |

The relative amplitude resolution, i.e. full width at half maximum, is determined from the measured data at the beginning of the scale $\delta_{ao}$ and at the end of the scale $\delta_{ae}$ for the value of pulse rate $v = 0.01\ v_{max}$ ($\delta'_{ao}$ and $\delta'_{ae}$) and $v = v_{max}$ ($\delta''_{ao}$ and $\delta''_{ae}$).

The increase of the peak width is given by:

$$\sqrt{(\delta''_{ao})^2 - (\delta'_{ao})^2}$$

$$\sqrt{(\delta''_{ae})^2 - (\delta'_{ae})^2}$$

The shift of the peak position and the increase of the peak width shall not exceed the values stated in the relevant specifications.

### 4.9 *Live time error**

### 4.9.1 *Apparatus*

*a)* The pulse generator of Sub-clause 4.1.1 with the additional condition that the generator rate $\nu_p$ shall be much lower (about 100 to 1 000 times) than the live time clock rate and the maximum pulse rate $\nu_{max}$.

*b)* The radioactive source of Sub-clause 4.8.1*d)*.

*c)* A gamma-detector and amplifier system which is capable of producing a count rate of at least $\nu_{max}$.

*d)* A scaler and timer.

*Note.* – A low-level discriminator may be necessary to trigger certain types of scaler from analogue pulses.

### 4.9.2 *Preparation for a test*

The circuit diagram of a test is given in Figure 10, page 43. The pulser amplitude is adjusted to produce a peak in the upper part of the energy range, well clear of the radioactive source spectrum.

The pulser repetition rate ($\nu_p$) is determined accurately using the scaler and timer. It is necessary that background radiation with the source removed is negligible.

### 4.9.3 *Test procedure*

The analyzer is set to acquire in live time mode at the full pulse-height measurement range.

An acquisition of the generator pulses is made when the radioactive source is removed. The time should be sufficient for at least 100 000 counts to be acquired in the pulser peak. The pulser peak area is integrated and the result is divided by the pre-set live time to give the live time pulser peak rate $\nu_{Lo}$. In this case $\nu_p$ is equal to $\nu_{Lo}$.

The radioactive sources are used to provide the input pulse rate to the ADC equal to $\nu_{max}$ above the threshold of scaler (which is equal to $A_{min}$ of the analyzer) and the procedure given above is repeated.

The pulser peak area is integrated and divided by the pre-set live time to give $\nu'_{L\,max}$. Then the pulser is switched off and acquisition of the radioactive source generated spectrum is made. The area is integrated within the same limits as in the previous case, and $\nu''_{L\,max}$ is determined. The pulser peak area is calculated as:

$$\nu_{L\,max} = \nu'_{L\,max} - \nu''_{L\,max}$$

### 4.9.4 *Processing of measurement data*

The live time error is given by:

$$\left| 1 - \frac{\nu_p}{\nu_{L\,max}} \right|$$

It is permissible to determine the live time error at a few values of the input pulse rate to the ADC.

---

* This measurement is applicable to analyzers with automatic live time correction.

# APPENDIX A

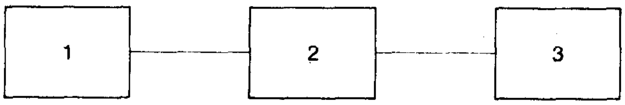
## LETTER SYMBOLS USED IN THIS STANDARD

$N_i$ = Number of counts in channel "i" (pulses).
$N_a$ = Arithmetic mean of the number of counts (pulses) in several channels.
$A_L$ = Measurable amplitude (V).
$A_{LN}$ = Rated value of the measurable amplitude.
$A_{min}$ = Minimum measurable signal amplitude.
$A_{max}$ = Maximum measurable signal amplitude.
$m_i$ = Number of channel "i".
$H$ = Channel width (V).
$a_o$ = Zero point, expressed in units of input parameter.
$K_i$ = Integral non-linearity (%).
$K_d$ = Differential non-linearity (%).
$\nu_{max}$ = Maximum pulse rate to be measured (pulse/second).
$\nu_p$ = Pulse repetition rate of generator.
$\nu_L$ = Live time pulser peak rate.
$\nu_{Lo}$ = Live time pulser peak rate (radioactive source removed).
$\nu_{L\,max}$ = Live time pulser peak rate (radioactive source used to give $\nu_{max}$).
$M$ = Maximum number of channels.
$T_{di}$ = Dead time of the analyzer corresponding to channel "i" for a definite input pulse shape.

$\delta_a$ = Relative amplitude resolution.

# APPENDIX B

## FIGURES



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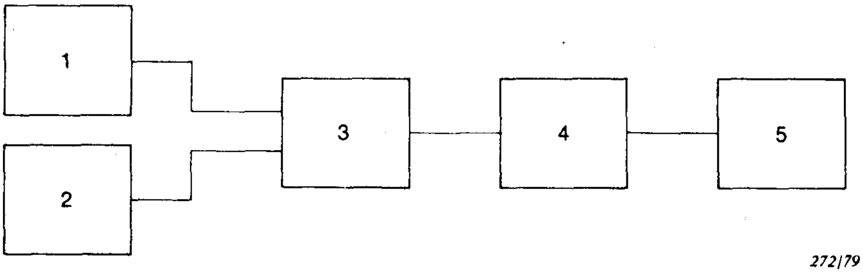
1 = precision pulse generator
2 = analyzer under test
3 = ratemeter

FIG. 1. – Block diagram for measurement of minimum and maximum measurable amplitudes.



272/79

1 = precision pulse generator
2 = white noise generator
3 = linear mixer
4 = analyzer under test
5 = digital printer

FIG. 2. – Block diagram for measurement of channel width, zero point and integral non-linearity.

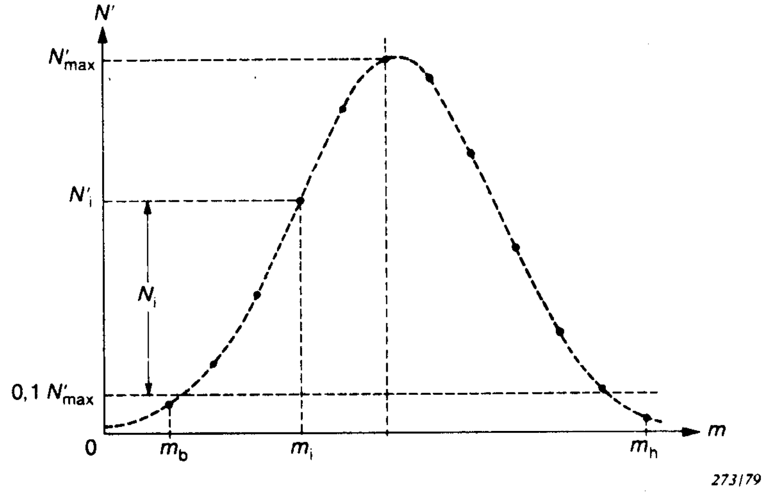


FIGURE 3a

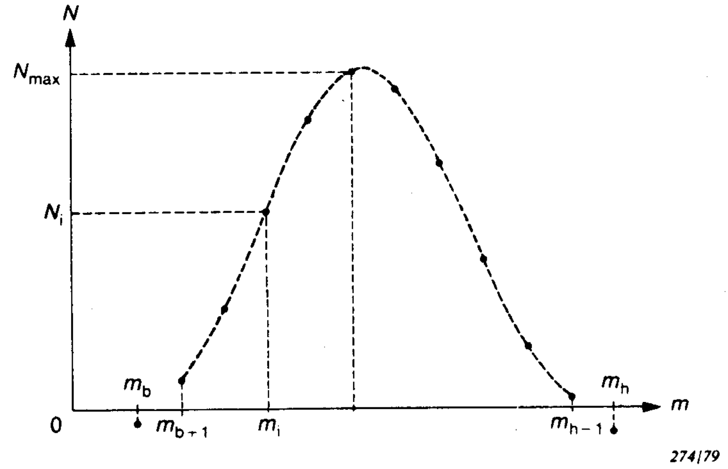


FIGURE 3b

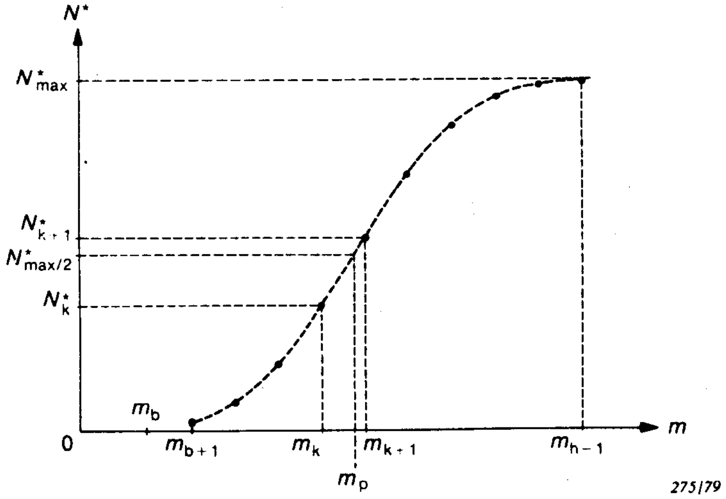


FIGURE 3c

FIG. 3. – Functions for peak position calculation

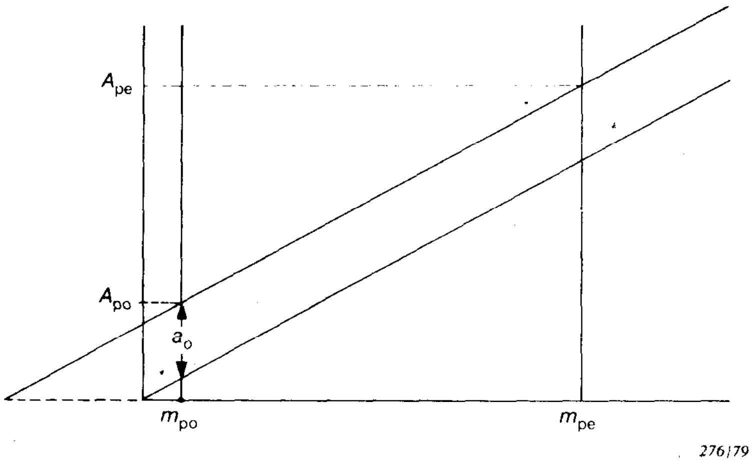


FIG. 4. – Intrinsic error of the zero point.

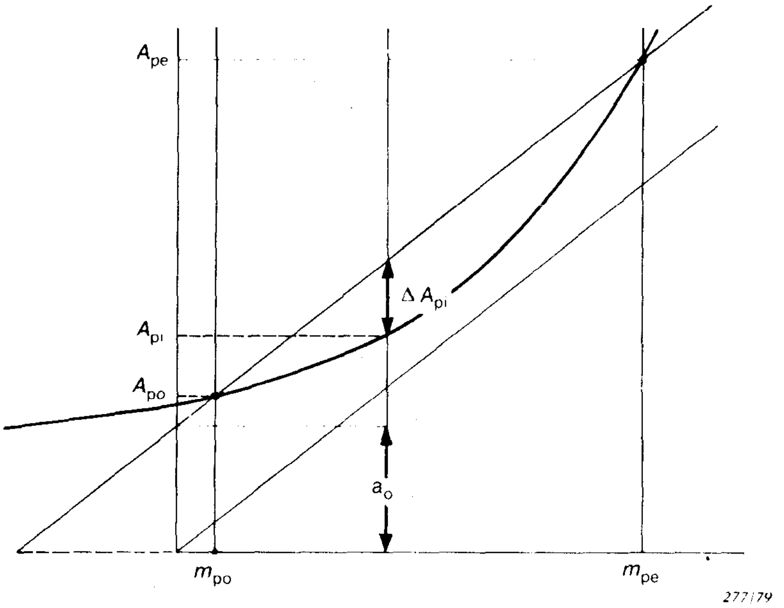
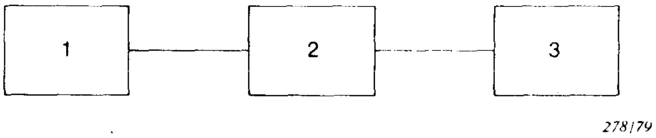


FIG. 5. – Deviation from the ideal linear amplitude response.



1 = generator of pulses with uniform density of pulse-height distribution probabilities
2 = analyzer under test
3 = digital printer

FIG. 6. – Block diagram for measurement of differential non-linearity of analyzers. General method.

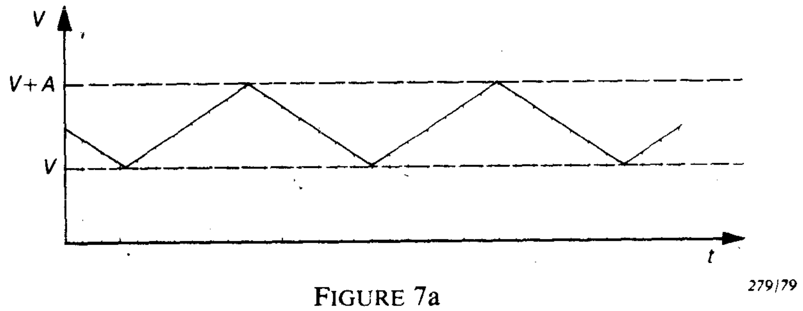
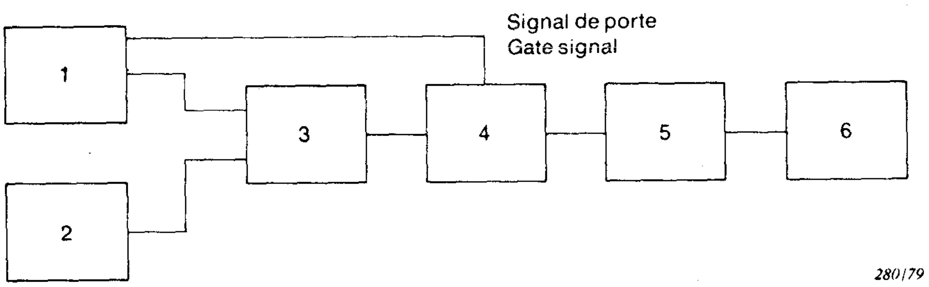
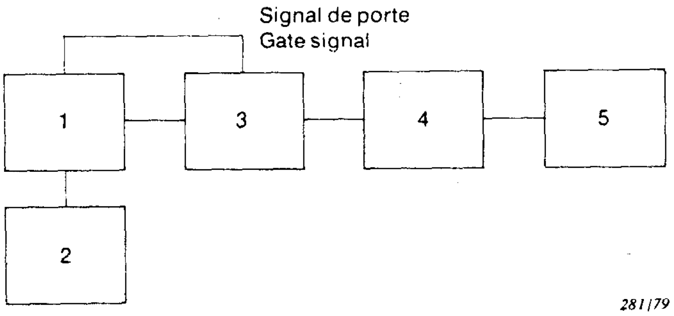


FIGURE 7a



1 = ramp generator
2 = adjustable d.c. source
3 = linear mixer
4 = linear gate
5 = analyzer under test
6 = digital printer

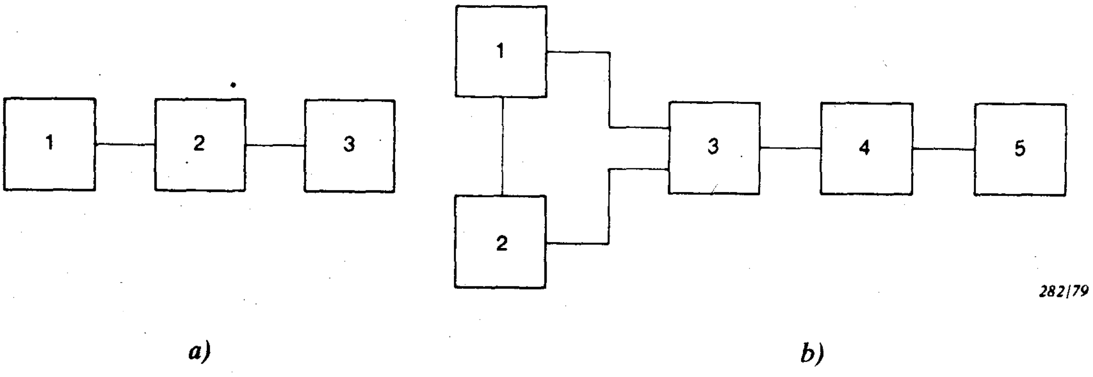
FIGURE 7b



1 = ramp generator
2 = adjustable d.c. source
3 = linear gate
4 = analyzer under test
5 = digital printer

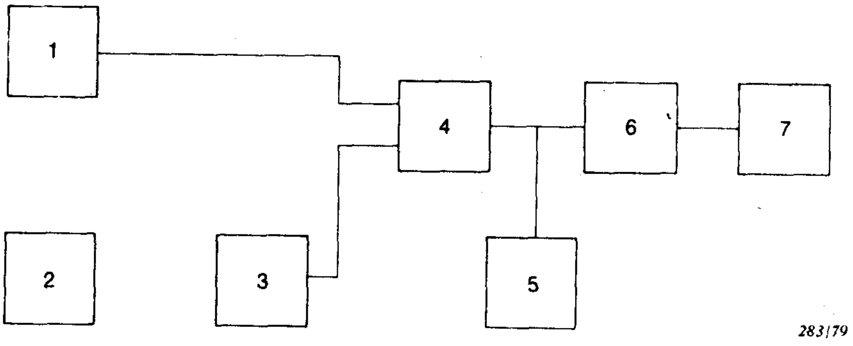
FIGURE 7c

FIG. 7. – Block diagrams for measurement of differential non-linearity of analyzers. Subsidiary method.



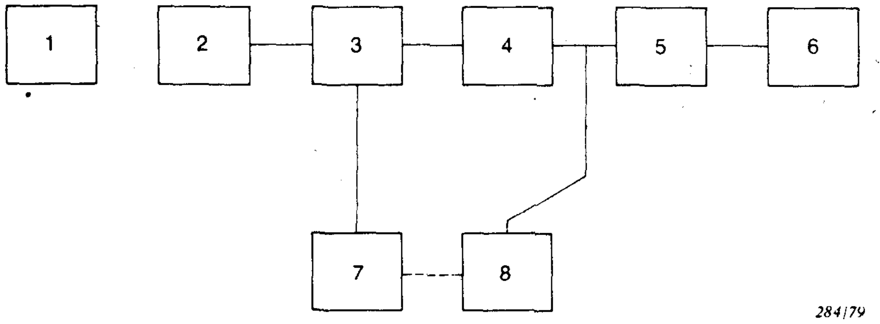
*a)* 1 = double-pulse generator
2 = analyzer under test
3 = digital printer
*b)* 1 and 2 = pulse generator
3 = linear mixer
4 = analyzer under test
5 = digital printer

FIG. 8. – Block diagram for measurement of dead time.



1 = precision pulse generator
2 = radioactive source (radionuclide $^{60}$Co)
3 = gamma-detector
4 = linear mixer
5 = ratemeter
6 = analyzer under test
7 = digital printer

FIG. 9. – Block diagram for measurement of maximum pulse rate.



1 = radioactive source (radionuclide $^{60}$Co)
2 = gamma-detector
3 = preamplifier
4 = main amplifier
5 = analyzer under test
6 = digital printer
7 = *pulse generator*
8 = scaler and timer
A = preamplifier test input

FIG. 10. – Block diagram for measurement of live-time error.